SECTION 26 32 13.00 20

DIESEL-GENERATOR SET, STATIONARY

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASME INTERNATIONAL (ASME)

ASME B16.1	(2005) Gray Iron Threaded Fittings; Classes 25, 125 and 250
ASME B16.21	(2005) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.3	(2006) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.5	(2009) Pipe Flanges and Flanged Fittings: NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	(2007) Standard for Factory-Made Wrought Steel Buttwelding Fittings

ASTM INTERNATIONAL (ASTM)

ASTM A 126	(2004; R 2009) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A 181/A 181M	(2006) Standard Specification for Carbon Steel Forgings, for General-Purpose Piping
ASTM A 193/A 193M	(2010a) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A 194/A 194M	(2010) Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A 234/A 234M	(2010) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A 53/A 53M	(2007) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM D 975 (2010a) Standard Specification for Diesel Fuel Oils

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 32 (1972; R 1990) Requirements, Terminaology, and Test Procedures for Neutral Grounding Devices

IEEE 115 (2009) Guide for Test Procedures for Synchronous Machines: Part I Acceptance and Performance Testing; Part II Test Procedures and Parameter Determination for Dynamic Analysis

IEEE 519 (1992; Errata 2004) Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

IEEE C2 (2007; TIA 2007-1; TIA 2007-2; TIA 2007-3; TIA 2007-4; TIA 2007-5; Errata 2006-1; Errata 2007-2; Errata 2009-3) National Electrical Safety Code

IEEE C50.12 (2005) Standard for Salient Pole 50 HZ and 60 Hz Synchronous Generators and Generation/Motors for Hydraulic Turbine Applications Rated 5 MVA and above

IEEE C57.13 (2008) Standard Requirements for Instrument Transformers

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS (2009) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60034-2A (1974) Rotating Electrical Machines Part 2: Methods for Determining Losses and Efficiency of Rotating Electrical Machinery from Tests (Excluding Machines for Traction Vehicles)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 3046 (1986; Am. 1) Reciprocating Internal Combustion Engines - Performance

ISO 8528 (1993; R 2005) Reciprocating Internal Combustion Engine Driven Alternating Current Generator Sets

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58 (2009) Pipe Hangers and Supports -

	Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-69	(2003) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)
MSS SP-70	(2006) Gray Iron Gate Valves, Flanged and Threaded Ends
MSS SP-71	(2005) Gray Iron Swing Check Valves, Flanged and Threaded Ends
MSS SP-80	(2008) Bronze Gate, Globe, Angle and Check Valves
MSS SP-85	(2002) Gray Iron Globe & Angle Valves Flanged and Threaded Ends

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA C50.10	(1990) Rotating Electrical Machinery - Synchronous Machines
NEMA ICS 6	(1993; R 2001; R 2006) Enclosures
NEMA MG 1	(2009) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 30	(2008; Errata 08-1) Flammable and Combustible Liquids Code
NFPA 37	(2010; TIA 10-1) Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 70	(2008) National Electrical Code
NFPA 110	(2010) Standard for Emergency and Standby Power Systems

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-461	(2007; Rev F) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

UNDERWRITERS LABORATORIES (UL)

UL 1236	(2006; R 2009; R 2010) Standard for Battery Chargers for Charging Engine-Starter Batteries
UL 467	(2007) Grounding and Bonding Equipment

1.2 RELATED REQUIREMENTS

Not Used.

1.3 SYSTEM DESCRIPTION

1.3.1 Engine-Generator Parameter Schedule

Power Rating:	1000 kW/1250 kVA Prime 0.8 pf lagging
Overload Capacity:	110 % of Service Load for 1 hour in 12 consecutive hours
Voltage:	400 volts, 3-phase wye, 50 Hz
Motor Starting kVA (maximum)	TBD by Army Corps of Engineers
Engine Speed	1500 rpm
Frequency Bandwidth	$\pm$ 0.25 percent
Voltage Regulation (No Load to Full Load)	$\pm$ 2 percent (maximum)
Voltage Bandwidth (Steady State)	$\pm$ 0.5 percent
Nonlinear Loads	TBD by Army Corps of Engineers
Max Step Load Increase at 0.8 pf	50 percent of rated load
Subtransient Reactance (X"d)	X"d greater than or equal to 17 percent
Transient Recovery Time with Step Load Increase (Voltage)	0.5 seconds
Transient Recovery Time with Step Load Increase (Frequency)	0.5 seconds
Maximum Voltage Deviation with Step Load Increase	10 percent of rated voltage
Maximum Frequency Deviation with Step Load Increase	5 percent of rated frequency
Max Step Load Decrease	100 percent of rated load at 0.8 pf
Max Time to Start and be Ready to Assume Load	10 seconds
Max Summer Outdoor Temp	40 degrees C
Min Winter Outdoor Temp (Ambient)	-21 degrees C
Installation Elevation	1798 meters above sea level

1.3.2 Engine-Generator Set Data

Submit data pertaining to the diesel engine-generator set and to the auxiliary equipment including but not limited to the following:

a. Make of engine.

b. Type or model of engine.

c. Gross bhp rating of engine shall be the total rated power output before deducting power requirements of electric motor-driven equipment or engine driven radiator fan.

d. Net brake power rating of engine shall include deductions for the total power requirements of electric motor-driven or engine-driven accessories as defined in ISO 3046. Net ratings shall include a deduction in power output for cooling media system power requirements including radiator fans and any other power consuming devices required to provide cooling as specified.

e. Strokes per cycle.

f. Number of cylinders.

g. Bore and stroke, (mm).

h. Engine speed, rpm.

i. Piston speed, (m/s).

j. kW power rating of engine-generator set as defined in the paragraph entitled "Engine-Generator Set Ratings and Performance."

k. Induction method (naturally aspirated, turbocharged).

l. Intercooler type (air-to-air or jacket water).

m. Governor type, make, and model.

n. Make and model of turbochargers.

1.3.3 Engine-Generator Set Efficiencies

Submit data pertaining to the diesel engine-generator set including but not limited to the following: Loads shall be calculated on basis of rated engine-generator set power.

a. Fuel consumption at 0.80 power factor, (liters per hr).

    1. 1/2 load

    2. 3/4 load

    3. Full load

b. Generator efficiency at 0.80 power factor (percent) in accordance with IEC 60034-2A.

    1. 1/2 load

2. 3/4 load

3. Full load

c. Radiator capacity at design conditions.

1. Coolant shall be antifreeze mixture as specified under paragraph entitled "Cooling System."

2. (L/s) of coolant

3. (L/s) of air through radiator

4. (kW) of heat exchange based on optimum coolant temperature to and from engine.

1.3.4 Diesel Engine Data

Submit data certified by the engine manufacturer including but not limited to the following: Loads shall be calculated on basis of rated engine-generator set power.

a. Approximate exhaust temperature degrees (C) at full load

b. Weight of exhaust gas at full load (kg per hr)

c. Weight of intake air at full load (kg per hr)

d. Total heat rejected at full load (kW)

1. To jacket coolant system

2. To fuel oil cooling system

e. Emissions (Lbs/hr)(kg/hr) at full load

1. Total Suspended Particulate

2. Particulate matter with an average aerodynamic diameter of 10 microns (PM-10)

3. Sulfur dioxides

4. Nitrogen Oxides (as N02)

5. Carbon Monoxide

6. Volatile Organic Compounds

f. Visible Emissions (percent opacity) at full load

1.3.5 Generator Data

Submit complete manufacturer's data for the furnished generators, including impedances, transient and subtransient reactances, time constants, and short circuit data; and generator capability curves showing generator kVA output capability (kW vs. kVAR) for both leading and lagging power factors ranging from 0 to 1.0.

Submit manufacturer's standard catalog data describing and depicting each engine-generator set and all ancillary equipment in sufficient detail to demonstrate complete specification compliance.

1.3.6 Capacity Calculations for Engine-Generator Set

Calculations shall verify that the engine-generator set power rating is adequate for the load described in the paragraph entitled "Load Profile."

1.3.7 Calculations for Brake Mean Effective Pressure (BMEP)

Calculation shall verify that the diesel engine meets the specified maximum BMEP as follows:

a. kW: Minimum power rating of engine-generator set as defined in the paragraph entitled "Engine-Generator Set Ratings and Performance."

b. rpm: Engine revolutions per minute.

c. (liters): Total engine piston displacement in (liters).

d. GEN.EFF.: Generator efficiency.

e. x: Multiplication sign.

f. (bkW'): Brake (kW) required from diesel engine by generator loaded to full power rating.

g. (bkW'): (kW/GEN.EFF.).

h. bkW": Brake (kW) required by diesel engine driven fan for cooling radiator or motor driven fan for cooling radiator.

i. (bkW): (bkW' + bkW").

j. BMEP kPa: (120,000 x bkW) /(rpm x liters).

1.3.8 Torsional Vibration Stress Analysis Computations

Torsional vibrational stresses in the crankshaft and generator shaft of assembled diesel engine and driven generator shall not exceed 34,450 kPa when engine is driving generator at rated speed while assembled unit is loaded to rated engine-generator set power. Computations shall be based on a mathematical model of the assembled generator set provided or based on calculations using measured values from tests on a unit identical to the one provided. Calculations based on models of, or measured data from, the unassembled engine and generator will not be acceptable. Calculations shall include:

a. A description of the system relating information pertinent to analysis such as operating speed range and identification plate data.

b. A mass elastic assembly drawing, showing the arrangement of the units in the generator set and dimensions of shafting, including minimum diameters (or section moduli) of shafting in the system.

c. A labeled line diagram of the mass elastic system indicating values of

masses, stiffness, equivalent lengths, and equivalent diameters including basic assumptions and definition of terms.

d. Sample computations showing procedures used to obtain resulting stress values.

e. Computations indicating assembled engine-generator speed of 1800 rpm with assembly loaded to rated generator power and the resulting computed critical torsional stress values in the assembled engine crankshaft and generator shaft.

1.3.9 Capacity Calculations for Batteries

Calculation shall verify that the engine starting battery capacity exceeds dc power requirements.

1.3.10 Turbocharger Load Calculations

When the proposed exhaust system layout is different from that shown on the contract drawings, submit calculations showing that the external loads from the exhaust system such as weight and thermal expansion do not exceed the engine manufacturer's maximum allowed forces and moments on the turbocharger.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Engine-Generator set and auxiliary equipment; G

SD-03 Product Data

Engine-generator set data; G

Engine-generator set efficiencies; G

Diesel engine data; G

Generator; G

SD-05 Design Data

Capacity calculations for engine-generator set; G

Calculations for brake mean effective pressure; G

Torsional vibration stress analysis computations; G

Capacity calculations for batteries; G

Turbocharger load calculations; G

Emissions calculations; G

SD-06 Test Reports

Acceptance checks and tests; G

Functional acceptance tests; G

Functional acceptance test procedure; G

SD-07 Certificates

Vibration isolation system certification G

Fuel system certification; G;

Start-up engineer qualification resume; G

Instructor's qualification resume; G

Compliance with EPA Emissions Requirements; G

SD-09 Manufacturer's Field Reports

Engine tests; G

Generator tests; G

Assembled engine-generator set tests; G

SD-10 Operation and Maintenance Data

Diesel engine-generator set, Data Package 4; G

Auxiliary systems and equipment, Data Package 4; G

Preliminary assembled operation and maintenance manuals; G

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and the paragraph entitled "Assembled Operation and Maintenance Manuals."

SD-11 Closeout Submittals

Posted operating instructions; G

Training plan; G;

1.5 QUALITY ASSURANCE

1.5.1 Drawing Requirements

Submit drawings pertaining to the engine-generator set and auxiliary equipment, including but not limited to the following:

a. Certified outline, general arrangement (setting plan), and anchor bolt details. Show total weight and center of gravity of assembled equipment on the steel subbase.

b. Detailed elementary, schematic wiring, and interconnection diagrams of the engine starting system, jacket coolant heating system, engine

protective devices, engine alarm devices, engine speed governor system, generator and excitation system, and other integral devices.

c. Detailed elementary, schematic wiring; and interconnection diagrams of the diesel fuel system, starting battery system, engine-generator control panel.

d. Dimensional drawings or catalog cuts of exhaust silencers, radiator, diesel fuel day tanks, fuel oil cooler, valves and pumps, intake filters, vibration isolators, and other auxiliary equipment not integral with the engine-generator set.

1.5.2 Vibration Isolation System Certification

Submit certification from the manufacturer that the vibration isolation system will reduce the vibration to the limits specified in the paragraph entitled "Vibration Isolation System."

1.5.3 Fuel System Certification

When the diesel fuel system requires a fuel oil cooler as described in the paragraph entitled "Fuel Oil Cooler," submit certification from the engine manufacturer that the fuel system design is satisfactory.

1.6 DELIVERY, STORAGE, AND HANDLING

Deliver equipment on pallets or blocking wrapped in heavy-duty plastic, sealed to protect parts and assemblies from moisture and dirt. Plug piping, conduit, exhaust, and air intake openings. Protect and prepare batteries for shipment as recommended by the battery manufacturer. Store auxiliary equipment at the site in covered enclosures, protected from atmospheric moisture, dirt, and ground water.

1.7 SEISMIC REQUIREMENTS

Seismic requirements shall be in accordance 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT. Equipment shall be suitable for Seismic Zone for Kabul, Afghanistan.

1.8 MAINTENANCE

1.8.1 Extra Materials

1.8.1.1 Paint

Furnish 4 liters of identical paint used on engine-generator set in manufacturer's sealed container with each engine-generator set.

1.8.1.2 Filters

For each DG unit, furnish spare replacement elements in their original containers suitable for 3 years operation at 1000 hours per year.for each filter with each unit.

1.8.2 Posted Operating Instructions

Provide proposed operating instructions for the engine-generator set and auxiliary equipment laminated between matte-surface thermoplastic sheets and suitable for placement adjacent to corresponding equipment. After

approval, install operating instructions where directed.

PART 2 PRODUCTS

2.1 DIESEL ENGINE-GENERATOR SET

Provide diesel engine-generator sets consisting of a water cooled diesel engine direct connected to an ac generator with a brushless excitation system and accessories. Equipment and materials shall be the manufacturer's standard products offered in catalogs for commercial or industrial use.

2.1.1 Engine-Generator Set Ratings and Performance

ISO 8528. Coordinate the engine-generator set performance to ensure an installed rating in the environment described in paragraph entitled "Site Conditions." The power of the engine-generator set is defined as the power output available at the generator terminals excluding the electrical power absorbed by the essential independent auxiliaries. Essential independent auxiliaries are items of equipment which are essential for the continued or repeated operation of the engine which uses power supplied from a source other than the engine.

2.1.1.1 Diesel Engine Capacity

The engine capacity shall be based on the following:

a. Engine burning diesel fuel conforming to ASTM D 975, Grade 2-D, at an ambient temperature of (29 degrees C).

b. Engine cooled by a radiator fan mechanically driven by the diesel engine or remote with a motor driven fan.

c. Engine cooled by coolant mixture of water and ethylene glycol, 50 percent by volume of each.

2.1.1.2 Diesel Engine Emission Limits

Emissions from the operation of the engine-generator set shall not exceed current EPA emissions requirements. The engine manufacturer shall submit emissions calculations and documentation certifying compliance with EPA emissions requirements.

2.1.2 Diesel Engines and Accessories

ISO 3046. Diesel engines shall be four-cycle naturally aspirated, or turbocharged, or turbocharged and intercooled; vertical in-line or vertical Vee type; designed for stationary service. Engines shall be capable of immediate acceleration from rest to normal speed without intermediate idle/warm up period or prelubrication to provide essential electrical power. Two-cycle engines are not acceptable.

2.1.2.1 Subbase Mounting

Mount each engine-generator set on a structural steel subbase sized to support the engine, generator, and necessary accessories, auxiliaries and control equipment to produce a complete self-contained unit as standard with the manufacturer. Design the structural subbase to properly support the equipment and maintain proper alignment of the engine-generator set in

the specified seismic zone. In addition, provide subbase with both lifting rings and jacking pads properly located to facilitate shipping and installation of the unit. Factory align engine and generator on the subbase and securely bolt into place in accordance with the manufacturer's standard practice. Crankshaft shall have rigid coupling for connection to the generator.

2.1.2.2 Assembly

Completely shop assemble each engine-generator set on its structural steel subbase. Paint entire unit with manufacturer's standard paints and colors. After factory tests and before shipping, thoroughly clean and retouch painting as necessary to provide complete protection.

2.1.2.3 Turbocharger

If required by the manufacturer to meet the engine-generator set rating, provide turbine type driven by exhaust gas from engine cylinders, and direct connected to the blower supplying air to the engine intake manifold.

2.1.2.4 Intercooler

Provide manufacturer's standard intercooler for engine size specified.

2.1.2.5 Crankcase Protection

Provide manufacturer's standard method of preventing crankcase explosions and standard method of crankcase ventilation.

2.1.2.6 Engine Lubricating Oil System

Each engine shall have a separate lube-oil system conforming to NFPA 30 and NFPA 37. Each system shall be pressurized by engine-driven pumps. System pressure shall be regulated as recommended by the engine manufacturer. A pressure relief valve shall be provided on the crankcase for closed systems. The crankcase shall be vented in accordance with the manufacturer's recommendation except that it shall not be vented to the engine exhaust system. Crankcase breathers, if provided on engines installed in buildings, shall be piped to vent to the outside. The system shall be readily accessible for service such as draining, refilling, etc. Each system shall permit addition of oil and have oil-level indication with the set operating. The system shall utilize an oil cooler as recommended by the engine manufacturer. Provide one full-flow filter for each pump. The filter shall be readily accessible and capable of being changed without disconnecting the piping or disturbing other components. The filter shall have inlet and outlet connections plainly marked.

Equip each engine with lube-oil pressure and temperataure sensors located downstream of the filters and provide signals for required indication and alarms. Provide lube-oil pre-heating as specified in paragraph entitled "Hot Start System."

2.1.2.7 Engine Cooling System

Provide each engine with the manufacturer's standard, engine-driven jacket water pump. Provide a thermostatic control valve in the jacket coolant system for each engine-generator set to maintain a constant jacket coolant temperature to the engine. Provide coolant temperature sensors with signals for pre-high and high indications and alarms. The cooling system coolant

shall use a combination of water and ethylene-glycol sufficient for freeze protection at the minimum winter outdoor temperature specified. The maximum temperature rise of the coolant across each engine shall not exceed that recommended and submitted in paragraph entiled "SUBMITTALS".

2.1.2.8 Engine Fuel System

The fuel system for each engine shall conform to the requirements of NFPA 30 and NFPA 37. The fuel system shall regulate fuel flow to the engine to maintain constant rated speed regardless of load variations. The fuel system shall consist of electronic fuel injectors, solid state engine control module (ECM), sensors, an engine-driven main fuel pump, actuators, filters, relief valves, and an integral data link from the ECM to the engine monitoring and control panel (EMCP; see paragraph entitled "DG CONTROLS AND MONITORING").

Provide each engine with fuel system integral with the engine, complete with necessary piping, fittings, and valves for connecting items of equipment which are a part of the system. Provide engine manufacturer's standard hand priming pump. Provide manufacturer's standardduplex filter for each engine, of the throwaway filter element type, consisting of shell filter elements, drains, and necessary connections and fittings. Arrange duplex filter such that flow may be diverted from one chamber to the other without interruption at any point of the changeover. Provide a relief/bypass valve to regulate pressure in the fuel supply line, return excess fuel to a return line and prevent the build-up of excessive pressure in the fuel system.

The engine-driven main fuel pump shall supply fuel at a minimum rate sufficient to provide the amount of fuel required to meet the performance indicated within the parameter schedule. The fuel flow rate shall be based on meeting the load requirements and all necessary recirculation.

2.1.2.9 Engine Intake Filter

Provide intake filter assemblies for each engine of the oil bath or dry type, as standard with the manufacturer. Filters shall be capable of removing a minimum of 92 percent of dirt and abrasive 3 microns and larger from intake air. Size filters to suit engine requirements at 100 percent of rated full load. Design unit for field access for maintenance purposes.

2.1.2.10 Engine Starting System

Provide 24 VDC electric starting with negative ground, and complete with battery, dual battery chargers, and cranking motor. Components shall be sized so they will not be damaged during a full engine-cranking cycle. Provide heavy-duty cranking motor that automatically engages and releases from the engine flywheel without binding. Cranking cycle shall be as required by NFPA 110, Level 1. Provide redundant cranking motors.

Lead calcium batteries shall be provided with adequate capacity to operate the required cranking cycle at least twice without recharging. Batteries shall be floor-mounted adjacent to the engine skid.

Dual 24 volt, current-limiting float chargers shall be provided and factory-mounted on the engine skid. Battery chargers shall comply with UL 1236. Chargers shall be automatic equalizing with solid state voltage regulation. Each charger shall be capable of an equalize-charging rate for recharging fully-depleted batteries within 24 hours, which is manually

adjustable in a continuous range, and a floating charge rate for maintaining the batteries at fully charged condition. Chargers shall have 230 or 400 volt, single-phase, 50 Hz input voltage, and 30 amps minimum continuous dc output. Chargers shall have standard indications and alarms, including: dc ammeter and voltmeter, "equalize on" light, equalize test button or switch, ac input circuit breaker, dc output circuit breaker, and alarm relays providing alarms as specified in paragraph entitled "DG CCONTROLS AND MONITORING." Wire all alarms to the EMCP.

2.1.2.11 Hot Start System

Provide a packaged hot start system which maintains engine coolant and lubricating oil within plus or minus 3 degrees of the control temperatures to assist with start-up and increase the engine lifecycle. Provide programmable logic controller (PLC) to control electric heaters independently of the engine to maintain favorable starting conditions while the generator is in a standby mode. The hot start unit be complete with circulating pumps, heaters, relief valves and controls, all integrally piped, linked and mounted for a vertical installation. Manufacturer shall conduct hot start system routine tests in accordance with their standard procedures and submit a written report containing the results. The hot start system shall be Kim Hotstart Model DV or approved equal.

The heated coolant shall be pumped by the unit through the engine cooling system while the engine is shut down. A check valve shall be installed between the unit and the engine which limits coolant backflow while the engine is operating. The heating system shall be designed to run continuously when the engine is not running. The heating element shall cycle on and off to maintain temperature.

Heated oil shall be pumped by the unit to the oil sump while the engine is shut down. A solenoid valve shall be provided in the return line between the unit and sump that will allow heated oil to be redirected through the engine's lubricating system to perform a pre-lubricating function. The solenoid valve shall be cycled on a schedule as determined by the generator integrating contractor and programmed into the PLC. The valve shall be sized consistent with the flow and pressure recommendations of the engine manufacturer. The heating system shall be designed to run continuously when the engine is not running. The heating element will cycle on and off to maintain temperature.

Hot start system shall include a PLC to provide complete system control, conduct system diagnostics, and display status messages. PLC shall be capable of receiving a 24 VDC signal to initiate/terminate its control algorithm. A 24 VDC output shall be provided to operate a 3-way solenoid valve in the lube-oil line to perform the pre-lube function on a set schedule. The schedule will be determined by the generator integrating contractor and shall be programmed into the PLC. Another output shall be capable of sending a general fault or trouble signal to the SCADA System. A text display with keypad shall be provided on the outside of the control box that shows diagnostic messages and allows user interface. Coolant temperature shall be field-adjustable using the keypad from 60 degrees F through 90 degrees F. Lube-oil temperature shall be field-adjustable from 80 degrees F through 160 degrees F. The PLC shall display any current error codes and have the capability of storing the three most recent errors. Motor protection switches shall be provided to safeguard against overloads and short-circuits. Diagnostics shall include, but not be limited to: heating element status, flow errors, low/over temperatures, thermocouple status, and motor protective switch status. Power to the unit

shall be 400 volts, 3-phase, 50 Hz.

2.1.2.12 Miscellaneous Engine Accessories

Provide the following engine accessories where the manufacturer's standard design permits:

a. Piping on engine to inlet and outlet connections, including nonstandard companion flanges.

b. Structural steel subbase and vibration isolators, foundation bolts, nuts, and pipe sleeves.

c. Level jack screws or shims, as required.

d. Rails, chocks, and shims for installation of subbase on the foundation.

e. Removable guard, around fan. Support guard, on engine subbase, to suit manufacturer's standard.

2.1.3 Generator and Excitation System

2.1.3.1 Generator

Provide salient-pole type, ac, brushless-excited, revolving field, air-cooled, self-ventilated, dripproof guarded, coupled type, synchronous generator conforming to NEMA MG 1, Part 32, NEMA C50.10, and IEEE C50.12. Generator shall be rated for continuous duty at 100 percent of the power rating of the engine-generator set as specified in paragraph entitled "Engine-Generator Set Ratings and Performance." Winding insulation shall be Class H (180 degrees C). Based upon 40 degrees C ambient temperature and a 10 degrees C hot spot allowance, the temperature rises at namplate rating when measured by resistance shall not exceed 80 degrees C.

a. Stator: Stator windings shall be 2/3 pitch design with form wound coils.

b. Rotor: The rotor shall have connected amortisser windings.

d. Grounding: Provide non-corrosive steel grounding pads located at two opposite mounting legs.

d. Filters: Provide manufacturer's standard generator cooling air filter assembly.

2.1.3.2 Current Balance

At 100 percent rated output capacity, and load impedance equal for each of the 3 phases, the permissible current difference between any 2 phases shall not exceed 2 percent of the largest current on either of the 2 phases.

2.1.3.3 Voltage Balance

At any balanced load between 75 and 100 percent of rated output capacity, the difference in line-to-neutral voltage among the 3 phases shall not exceed 1 percent of the average line-to-neutral voltage. For a single-phase load condition, consisting of 25 percent load at unity power factor placed between any phase and neutral with no load on the other 2 phases, the maximum simultaneous difference in line-to-neutral voltage between the phases shall not exceed 3 percent of rated line to neutral

voltage. The single-phase load requirement shall be valid utilizing normal exciter and regulator control. The interpretation of the 25 percent load for single phase load conditions means 25 percent of rated current at rated phase voltage and unity power factor.

2.1.3.4 Waveform

The deviation factor of the line-to-line voltage at zero load and at balanced rated output capacity shall not exceed 10 percent. The RMS of all harmonics shall be less than 5.0 percent and that of any one harmonic less than 3.0 percent of the fundamental at rated output capacity. Each engine-generator shall be designed and configured to meet the total harmonic distortion limits of IEEE 519.

2.1.3.5 Load Sharing

Load sharing and load control shall be performed by a separate digital synchronizing and load control (DSLC) unit located in the generator switchgear. A dedicated current transformer shall be provided with the generator and connected to the regulator parallel compensation terminals. Cross-current compensation between generators shall not be required for parallel operation.

2.1.3.6 Current Transformers

Current transformers (CT) shall conform to the requirements of IEEE C57.13. The terminals of each CT, including all connections from multi-ratio CTs, shall be wired to a separate 6-point, shorting-type terminal block using 12 AWG, 600 volt, Type SIS switchboard wire with yellow insulation. Terminal blocks shall be located in a readily accessible control enclosure mounted on the side of the generator. Terminal blocks shall be General Electric EB-27 or approved equal.

Provide six 2000:5 multi-ratio CTs in the generator terminal box of each engine-generator set. Three CTs shall be mounted on the neutral leads of the generator for differential relay use, and three CTs shall be mounted on the line side leads for EMCP use, as indicated on the drawings. CTs shall have C200 relay accuracy at 2000:5 and shall be ITI Model 781 or approved equal.

2.1.3.7 Temperature Sensing

Provide six stator winding temperature RTDs and two generator bearing temperature RTDs in each generator wired to terminal blocks in a control enclosure mounted on the side of the generator. Provide a manufacturer's standard RTD module in the control enclosure or in the EMCP, and wire RTDs to the RTD module. The RTD module shall be connected to the EMCP via a data link for shutdowns, alarms, and remote indication of generator temperatures.

2.1.3.8 Generator Space Heaters

Provide 230 or 400 volt ac heaters. Heater capacity shall be as recommended by the generator manufacturer to aid in keeping the generator insulation dry.

2.1.3.9 Excitation System

Provide a brushless excitation system consisting of an exciter, rotating rectifier assembly, and permanent magnet generator Insulation class for

parts integral with the generator shall be as specified in paragraph entitled "Generator." System shall provide a minimum short circuit of 300 percent rated engine-generator set current for at least 10 seconds. Steady state voltage regulation shall be in accordance with the operating limit values of the performance class specified in the paragraph entitled "Performance Class." Provide surge voltage protection for rectifiers. Provide a voltage spike suppression device for the permanent magnet generator.

2.1.3.10 Voltage Regulator

Provide a solid-state voltage regulator separate from the exciter. The regulator shall maintain the voltage within a bandwidth of the rated voltage, over a steady-state load range of zero to 100 percent of rated output capacity. Regulator shall be configured for safe manual adjustment of the engine-generator voltage output without special tools, during operation, from 90 to 110 percent of the rated voltage over the steady state load range of 0 to 100 percent of rated output capacity. Regulation drift shall not exceed plus or minus 0.5 percent for an ambient temperature change of (20 degrees C). Reactive droop compensation or reactive differential compensation shall load share the reactive load proportionally between sets during parallel operation. The voltage regulator shall have a maximum droop of 2 percent of rated voltage over a load range from 0 to 100 percent of rated output capacity and automatically maintain the generator output voltage within the specified operational bandwidth. Provide overexcitation shutdown protection with the regulator. Provide single ratio current transformer for voltage regulator, together with shorting terminal block, meeting the requirements of paragraph "Current Transformers".

2.1.3.11 Electromagnetic Interference (EMI) Suppression

Provide as an integral part of the generator and excitation system, EMI suppression complying with MIL-STD-461.

2.2 ENGINE-GENERATOR SET AUXILIARY SYSTEMS AND EQUIPMENT

Provide auxiliary systems and equipment designed for continuous duty at 100 percent of the power rating of the engine-generator set as specified in the paragraph entitled "Engine-Generator Set Ratings and Performance."

2.2.1 Vibration Isolation System

Install the subbase on vibration isolators that are secured to a suitable concrete foundation. Provide isolators as recommended by the engine-generator set and isolator manufacturers and provide integral or external lateral support to limit lateral movement and overturning moments. The isolation system shall reduce the vibration transmitted to the adjacent floor slab to a maximum of (0.038 mm) total amplitude throughout the frequency range down to 65 Hz.

2.2.2 Exhaust System

Provide exhaust systems for each engine.

2.2.2.1 Exhaust Silencers

A critical class silencer shall be provided for each engine which will reduce the exhaust sound spectrum by the following listed values at a (23 m)

radius from the outlet, with generator set loaded to rated capacity and clear weather. Inlet and outlet connections shall be flanged.

	-----Octave Band Center Frequency (Hertz)-------							
	63	125	250	500	1000	2000	4000	8000
Minimum Silencer Attenuation Decibels:	15	32	37	36	30	36	37	37

2.2.2.2 Field Installed Exhaust Piping System

Field installed exhaust piping shall conform to the following:

a. Exhaust Piping: Provide flanges for connections to diesel engines, exhaust mufflers, and flexible connections. Provide steel pipe conforming to ASTM A 53/A 53M for each engine complete with necessary fittings, flanges, gaskets, bolts, and nuts. Exhaust piping shall be Schedule 40 pipe for (300 mm) and smaller, standard weight for sizes (350 mm) through (600 mm), and (6 mm) wall thickness for sizes larger than (600 mm). Flanges shall be Class 150 slip-on forged steel welding flanges in accordance with ASME B16.5, with material in accordance with ASTM A 181/A 181M, Grade I. Fittings shall be buttwelding conforming to ASTM A 234/A 234M, with wall thickness same as adjoining piping. Fittings shall be of same material and wall thickness as pipe. Built-up miter welded fittings may be used. Miter angles of each individual section shall not exceed 22.5 degrees total and not more than 11.25 degrees relative to the axis of the pipe at any one cut. Gaskets for exhaust piping shall be of high temperature asbestos-free material suitable for the service and shall be ASME B16.21, composition ring, (1.6 mm) thick. Bolting material for exhaust flanges shall be alloy-steel bolt-studs conforming to ASTM A 193/A 193M, Grade B7 bolts and alloy-steel nuts conforming to ASTM A 194/A 194M, Grade 7. Bolts shall be of sufficient length to obtain full bearing on the nuts and shall project not more than two full threads beyond the nut. Provide stainless steel counterbalance type rain caps at termination of each exhaust pipe.

b. Expansion (Flexible) Joints: Provide sections of multiple corrugated stainless steel expansion joints with liners in the engine exhaust piping for each engine to absorb expansion strains and vibration transmitted to the piping. Flexible joints shall be suitable for operation at (93 degrees C) above normal exhaust gas temperature at 100 percent load, 10,000 cycles, minimum. Joints shall be flanged and located between engine exhaust manifold and exhaust piping, shall be the same size as exhaust piping size, and shall be designed and constructed for diesel engine exhaust service.

c. Hangers and Supports: MSS SP-58 and MSS SP-69.

d. Piping Sleeves: Provide where piping passes through masonry or concrete walls, floors, roofs, and partitions. Sleeves shall be placed during construction. Unless indicated otherwise, pipe sleeves shall comply with following requirements: sleeves in outside walls below and above grade, in floor, or in roof slabs, shall be standard weight zinc coated steel pipe. Sleeves in partitions shall be zinc coated sheet steel having a nominal weight of not less than (4.4 kg per square meter). Space between piping insulation and the sleeve shall not be less than (6 mm). Sleeves shall be held securely in proper position and location during construction. Sleeves shall be sufficient length to pass through entire thickness of walls, partitions, or slabs. Sleeves in

floor slabs shall extend (50 mm) above the finished floor. Space between the pipe and the sleeve shall be firmly packed with insulation and calked at both ends of the sleeve with plastic waterproof cement.

e. Piping Insulation: Provide exhaust piping insulation in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.2.3 Cooling System

Provide the specified cooling water system. Properly size equipment to handle the flow rate and pressure losses of the coolant mixture specified in the paragraph entitled "Diesel Engine Capacity," and at the site elevation specified in the paragraph entitled "Site Conditions."

2.2.3.1 Radiators

Provide for each engine-generator set, as standard with the manufacturer.

a. Design Conditions: Each radiator unit shall have ample capacity to remove not less than the total (kW) of heat rejected by its respective engine at 100 percent full-rated load to the jacket water, fuel oil, and lubricating oil system, and intercooler. Radiator capacity shall be rated at optimum temperature of coolant leaving the engine and intercooler as recommended by the engine manufacturer for ambient temperature range as specified in the paragraph entitled "Engine-Generator Parameter Schedule" and with the coolant mixture specified in the paragraph entitled "Diesel Engine Capacity." Pressure drop through the radiator shall not exceed (41.34 kPa) when circulating the maximum required coolant flow. Radiator air velocity shall be a maximum of (7.6 meters per second).

b. Engine Mounted Radiator Construction: Radiator fan shall direct airflow from the engine outward through the radiator. Fan shall be V-belt driven directly from the engine crankshaft. Radiator fan shall have sufficient capacity to meet design conditions against a static restriction of 200 Pa. Fan static capacity shall be adjusted to suit the ductwork furnished. Cooling section shall have a tube and fin-type core consisting of copper or copper base alloy tubes with nonferrous fins. Select engine-driven fans for quiet vibration-free operation. Make provision for coolant expansion either by self-contained expansion tanks or separately mounted expansion tanks, as standard with the manufacturer. Provide suitable guards for each fan and drive.

c. Coolant solution shall be a mixture of clean water and ethylene glycol, 50 percent by volume each. Provide an anti-freeze solution tester suitable for the mixture.

2.2.3.2 Jacket Coolant Water Piping Systems

Field installed jacket coolant water piping shall conform to the following:

a. Piping: Provide seamless steel pipe, Schedule 40, conforming to ASTM A 53/A 53M, Grade A.

b. Fittings and Flanges: Fittings, (40 mm) or smaller, shall be malleable iron conforming to ASME B16.3 for Class 300 threaded type. Fittings, (50 mm) and larger, shall be steel buttwelding conforming to ASME B16.9. Utilize either ASME B16.1 or Class A of ASTM A 126 for Class 125 cast-iron flanged fittings. Flanges shall be Class 150 slip-on forged

steel welding flanges in accordance with ASME B16.5, with material in accordance with ASTM A 181/A 181M, Grade I. Provide flat face flanges for connecting to Class 125 standard cast-iron valves, fittings, and equipment connections.

c. Valves

1. Gate Valves: For valves, 40 mm and smaller, provide double disk, rising stem, inside screw, union bonnet type, Class 125 bronze material conforming to MSS SP-80. For valves, (50 mm) and larger, provide double-disk, parallel seat type, hydraulic-rated, Class 125, outside screw and yoke type with flanged ends and bronze trim conforming to MSS SP-70. Provide stem packing of material compatible with the system coolant.

2. Globe Valves: For valves, 40 mm and smaller, provide rising stem, inside screw, union bonnet type, Class 125 bronze valves conforming to MSS SP-80. For valves, (50 mm) and larger, provide Class 125 cast iron, flanged ends, bronze trim globe valves conforming to MSS SP-85. Valves shall have renewable composition or cast iron discs compatible with the system coolant.

3. Check Valves: MSS SP-71 or MSS SP-80, swing check type.

d. Hangers and Supports: MSS SP-58 and MSS SP-69.

e. Piping Sleeves: Provide where piping passes through masonry or concrete walls, floors, roofs, and partitions. Place sleeves during construction. Unless indicated otherwise, pipe sleeves shall comply with following requirements: Sleeves in outside walls below and above grade, in floor, or in roof slabs, shall be standard weight zinc coated steel pipe. Sleeves in partitions shall be zinc coated sheet steel having a nominal weight of not less than (4.4 kg per square meter). Space between piping insulation and the sleeve shall be not less than (6 mm). Sleeves shall be held securely in proper position and location during construction. Sleeves shall be of sufficient length to pass through entire thickness of walls, partitions, or slabs. Sleeves in floor slabs shall extend (50 mm) above the finished floor. Space between the pipe and the sleeve shall be firmly packed with insulation and calked at both ends of the sleeve with plastic waterproof cement.

2.2.4 Diesel Fuel System

NFPA 30 and NFPA 37 and the requirements herein.

2.2.4.1 Diesel Fuel Piping System

Factory installed piping shall conform to the engine manufacturer's standard. Provide flange connections in accordance with ASME B16.1 Class 125 flanges.

2.2.4.2 Diesel Fuel Day Tank

Provide a 300 gallon day tank integral in the skid (belly tank), with connections for fuel supply line, fuel return line, fuel overflow line, local fuel fill port, gauge, vent line, drain line, and float switch assembly for control. A fuel return line cooler shall be provided as recommended by the manufacturer and assembler. The temperature of the fuel returning to the day tank shall be below the flash point of the fuel.

Provide a temperature sensing device installed in the fuel supply line. Provide a leak detector switch that actuates when fuel is detected in containment basin, stops the fuel transfer pump, and closes the fuel oil solenoid valve.

2.2.4.3 Fuel Level Controls

Each day tank shall have a float-switch assembly to perform the following functions:

a. Start the supply of fuel into the day tank when the fuel level is at the low level mark, 75 percent of the rated tank capacity.

b. Stop the supply of fuel into the day tank when the fuel level is at 90 percent of the rated tank capacity.

c. Activate the "Overfill Fuel Level" alarm at 95 percent of the rated tank capacity.

d. Activate the "Low Fuel Level" alarm at 70 percent of the rated tank capacity.

e. Activate the automatic fuel supply shut-off valve located on the fill line of the day tank and close the shut-off valve at 90 percent of the rated tank capacity. The flow of fuel to all day tanks shall be stopped when the flow sensor in the overflow line senses flow.

2.2.4.4 Fuel Transfer Pump

Provide fuel transfer pump in each engine-generator enclosure. Pump shall be horizontal, positive displacement type. Direct-connect pump to motor through a flexible coupling. Equip each pump with a bypass relief valve, if not provided with an internal relief valve, and a fuel strainer. Provide motor and controller as required

2.2.5 Special Tools Required

All wrenches and tools that are specifically designed and required to work on the new equipment, which are not commercially available as standard mechanic's tools, shall be furnished to the Contracting Officer.

2.3 DG CONTROL AND MONITORING

A freestanding or wall-mounted enclosure shall be provided and installed near the generator terminal box. The enclosure shall contain the engine-generator manufacturer's engine monitoring and control panel (EMCP), mounted through the front door, voltage regulator, and other accessories specified in this spec section. The enclosure shall conform to NEMA ICS 6, and shall have a lockable, hinged front door.

2.3.1 Engine Monitoring and Control Panel

The EMCP shall be a manufacturer's standard, microprocessor-based unit with indications, alarms, shutdowns, and other controls, and fully integrated with the engine and generator. The EMCP shall be fully programmable to provide all shutdowns and alarms listed in NFPA 110, Table 5.6.5.2, Level 1 funtions. The shutdowns and alarms are summarized as follows:

Shutdowns

a. Overcrank (failure to start)
d. High engine (coolant) temperature
f. Low lube oil pressure
g. Overspeed
v. Remote emergency stop (from the PCMS system)
aa. Local emergenc stop (pushbutton on the EMCP)
bb. High generator bearing temperature.

Alarms
a. Overcrank (failure to start)
b. Low water temperature <
c. High engine (coolant) temperature pre-alarm
d. High engine (coolant) temperature alarm
e. Low lube oil pressure pre-alarm
f. Low lube oil pressure alarm
g. Overspeed
h. Day tank low fuel
i. Engine low coolant level
k. Local control switch not in remote (automatic)
l. High battery voltage
m. Low cranking voltage
n. Low batter voltage
o. Battery charger failure
s. Low starting air pressure (from dry contact on starting air tank)
cc. High generator stator temperature
dd. Day tank leak detected.

NOTE: Shutdowns and alarms ("a" through "s") are identified to correspond with required function listed in NFPA 110. The other shutdowns and alarms ("aa" through "dd") are identified as such for convenience. Shutdowns and alarms which are identified by the same letter designation in both lists shall activate at the same setpoint.

The EMCP shall be equipped with standard controls, engine and generator monitoring using an LCD display, audible and visual alarms and shutdowns, and provisions for J1939 or RS485 Modbus connection to the DSLC. No additional engine-mounted instruments or meters are required. The EMCP shall connect to the generator RTD module via an accessory data link. The EMCP shall be provided with a CD disk containing a back-up copy of the installed EMCP control software.

2.3.2 Digital Synchronizing and Load Control Unit (DSLC)

A digital synchronizing and load control unit (DSLC) shall be provided for automatic synchronizing of each DG unit across its generator breaker. The DSLC shall be connected to CTs at the switchgear, and to line and bus voltage transformers in the switchgear. The DSLC shall be mounted in the generator switchgear near its respective generator breaker. The DSLC shall provide for parallel operation, isochronous load sharing, and load control of multiple DG units as indicated. DSLCs will be provided with the generator switchgear as specified in Section 26 11 13.00 20

2.3.3 PCMS Interface

The EMCP and DSLC shall interface with the site power control and monitoring system (PCMS) as indicated on the drawings and as specified in Section 25 10 11 POWER CONTROL AND MONITORING SYSTEM (PCMS). Each DSLC shall have a data link to its respective network port, and shall be programmable (similar to a programmable logic controller (PLC)) to provide

discrete inputs and outputs for generator breaker control. The DSLC shall receive and execute remote commands from the PCMS system workstations as indicated on the drawings.

2.4 NEUTRAL GROUNDING RESISTOR

The neutral grounding resistor assembly shall comply with the IEEE 32. The assembly shall be designed for indoor use and shall meet the following:

a. The resistor element shall be stainless steel. The resistor shall be rated for connection in the neutral of the 400 volt generator, capable of carrying 400 amperes L-G fault current for 10 seconds, and have a resistance of 20 ohms.

b. The resistor shall be installed in an aluminized screened or stainless steel enclosure of the personnel safety type and shall be provided with any necessary supports and mounting hardware. The enclosure, including screening and support framing, shall have two finish coats applied over a prepared substrate. The color of the finish coats shall be ANSI 61 Gray. The resistor shall be mounted over the generator inside the overall DG unit enclosure

c. Provide one current transformer in the resistor enclosure with external connections as specified in Paragraph entitled "Current Transformers."

d. A 600 volts, 4/0 AWG copper neutral cable shall be provided from the generator to the primary terminal of the grounding resistor. A 600 volt, 4/0 AWG copper grounding conductor shall be provided from the resistor to a ground lug on the exterior wall of the DG unit enclosure for field connection to the grounding grid.

e. Manufacturer shall conduct neutral grounding resistor routine tests in accordance with IEEE 32 and submit a written report containing the results.

2.5 SCR SYSTEM

Provide selective catalytic reduction (SCR) system for treating engine exhaust to meet EPA Tier 4 (Final) emissions requirement. SCR system shall include local urea day tank and pumping means for injection into the exhaust stream. Main SCR equipment shall be mounted above the engine with brackets or floor supports as required on brackets.

2.6 DG UNIT ENCLOSURE

Provide a weatherproof outdoor enclosure for each engine-generator set and fabricate from zinc coated or phosphatized and shop primed 16 gage minimum sheet steel in accordance with the manufacturer's standard design. Provide a complete, weatherproof enclosure for the engine, generator, and auxiliary systems and equipment. Support exhaust piping, SCR system and silencer so that the turbocharger is not subjected to exhaust system weight or lateral forces generated in connecting piping that exceed the engine manufacturer's maximum allowed forces and moments. The housing shall have sufficient louvered openings to allow entrance of outside air for engine and generator cooling at full load. Design louvered openings to exclude driving rain and snow. Provide properly arranged and sized, hinged panels in the enclosure to allow convenient access to the engine, generator, and control equipment for maintenance and operational procedures. Provide hinged panels with

spring type latches which shall hold the panels closed securely and will not allow them to vibrate. Brace the housing internally to prevent excessive vibration when the set is in operation.

2.7 SPECIAL WRENCHES AND TOOLS

Wrenches and tools specifically designed and required to work on the new equipment, which are not commercially available as standard mechanic's tools, shall be furnished to the Contracting Officer.

2.8 IDENTIFICATION OF EQUIPMENT

Provide plates and tags sized so that inscription is readily legible to operating or maintenance personnel and securely mounted to or attached in proximity of their identified controls or equipment. Lettering shall be normal block lettering, a minimum of (6.4 mm) high.

2.8.1 Materials

Construct ID plates and tags of 16 gage minimum thickness bronze or stainless steel sheet metal engraved or stamped with inscription. Construct plates and tags not exposed to the weather or high operational temperature of the diesel engine of laminated plastic, (3.2 mm) thick, matte white finish with black center core, with lettering accurately aligned and engraved into the core.

2.8.2 Control Devices and Operation Indicators

Provide ID plates or tags for control devices and operation indicators, including valves, off-on switches, visual alarm annunciators, gages and thermometers, that are required for operation and maintenance of provided mechanical systems. Plates or tags shall be minimum of (13 mm) high and (50 mm) long and shall indicate component system and component function.

2.8.3 Equipment

Provide ID plates of a minimum size of (75 mm) high and (130 mm) long on provided equipment indicating the following information:

a. Manufacturer's name, address, type and model number, and serial number;

b. Contract number and accepted date;

c. Capacity or size;

d. System in which installed; and

e. System which it controls.

2.9 ASSEMBLED OPERATION AND MAINTENANCE MANUALS

The contents of the assembled operation and maintenance manuals shall include the manufacturer's O&M information required by the paragraph entitled "SD-10, Operation and Maintenance Data".

a. Manuals shall be in separate books or volumes, assembled and bound securely in durable, hard covered, water resistant binder, and indexed by major assembly and components in sequential order.

b. A table of contents (index) shall be made part of the assembled O&M. The manual shall be assembled in the order noted in table of contents.

c. The cover sheet or binder on each volume of the manuals shall be identified and marked with the words, "Operation and Maintenance Manual."

2.10 SOURCE QUALITY CONTROL

Perform and report on factory tests and inspections prior to shipment. Provide certified copies of manufacturer's test data and results. Test procedures shall conform to ASME, IEEE, IEC, and ANSI standards, and to ISO requirements on testing, as appropriate and applicable. The manufacturer performing the tests shall provide equipment, labor, and consumables necessary for tests and measuring and indicating devices shall be certified to be within calibration. Tests shall indicate satisfactory operation and attainment of specified performance. If satisfactory, equipment tested will be given a tentative approval. Equipment shall not be shipped before approval of the factory test reports for the following tests.

2.10.1 Engine Tests

Perform customary commercial factory tests in accordance with ISO 3046 on each engine and associated engine protective device, including, but not limited to the following:

a. Perform dynamometer test at rated power. Record horsepower at rated speed and nominal characteristics such as lubricating oil pressure, jacket water temperature, and ambient temperature.

b. Test and record the values that the low oil pressure alarm and protective shutdown devices actuate prior to assembly on the engine.

c. Test and record values that the high jacket water temperature alarm and protective shutdown devices actuate prior to assembly on the engine.

2.10.2 Generator Tests

Tests shall be performed on the complete factory assembled generator prior to shipment. Conduct tests in accordance with IEEE 115, NEMA C50.10, IEC 60034-2A, and NEMA MG 1.

2.10.2.1 Routine Tests

Perform the following routine tests on the generators and their exciters:

a. Resistance of armature and field windings

b. Mechanical balance

c. Phases sequence

d. Open circuit saturation curve and phase (voltage) balance test

e. Insulation resistance of armature and field windings

f. High potential test

2.10.2.2 Design Tests

Submit the following design tests made on prototype machines that are physically and electrically identical to the generators specified.

a. Temperature rise test

b. Short circuit saturation curve and current balance test

2.10.3 Assembled Engine-Generator Set Tests

Submit the following tests made on prototype machines that are physically and electrically identical to the engine-generator set specified.Perform the following tests on the assembled engine-generator set.

2.10.3.1 Initial Stabilization Readings

Operate the engine-generator set and allow the set to stabilize at rated kW at rated power factor, rated voltage, and rated frequency. During this period record instrument readings for output power (kW), terminal voltage, line current, power factor, frequency (rpm) generator (exciter) field voltage and current, lubricating oil pressure, jacket water temperature, and ambient temperature at minimum intervals of 15 minutes. Adjust the load, voltage, and frequency to maintain rated load at rated voltage and frequency. Adjustments to load, voltage, or frequency controls shall be recorded on the data sheet at the time of adjustment. Stabilization shall be considered to have occurred when four consecutive voltage and current recorded readings of the generator (or exciter) field either remain unchanged or have only minor variations about an equilibrium condition with no evident continued increase or decrease in value after the last adjustment to the load, voltage, or frequency has been made.

2.10.3.2 Regulator Range Test

Remove load and record instrument readings (after transients have subsided). Adjust voltage to the maximum attainable value or to a value just prior to actuation of the overvoltage protection device. Apply rated load and adjust voltage to the minimum attainable value or a value just prior to activation of the undervoltage protection device. The data sheets shall indicate the voltage regulation as a percent of rated voltage and the maximum and minimum voltages attainable. Voltage regulation shall be defined as follows:

$$\text{Percent Regulation} = \frac{(\text{No-Load Voltage}) - (\text{Rated-Load Voltage})) \times 100}{(\text{Rated-Load Voltage})}$$

2.10.3.3 Frequency Range Test

Adjust the engine-generator set frequency for the maximum attainable frequency at rated load. Record instrument readings. Adjust the engine-generator set frequency for the specified minimum attainable frequency at rated load. Record instrument readings. Reduce the load to zero and adjust the engine-generator set frequency for the maximum attainable frequency. Record instrument readings. Adjust the engine-generator set frequency for the minimum attainable frequency. Record instrument readings. The data sheet shall show the maximum and minimum frequencies attained at rated load, and at no load.

2.10.3.4 Transient Response Test

Drop the load to no load and re-apply rated load three times to ensure that the no load and rated load voltage and frequency values are repeatable and that the frequency and voltage regulation is within the limits specified. Record generator terminal voltage and frequency using a high speed strip chart recorder. The data sheet shall show the following results:

a. Frequency

1. Stability bandwidth or deviation in percent of rated frequency.

2. Recovery time.

3. Overshoot and undershoot.

b. Voltage

1. Stability bandwidth or deviation in percent of rated voltage.

2. Recovery time.

3. Overshoot and undershoot.

PART 3 EXECUTION

3.1 INSTALLATION

Installation shall conform to the applicable requirements of IEEE C2 NFPA 30, NFPA 37, and NFPA 70.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounding systems shall have a resistance to solid earth ground not exceeding 5 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02.00 20 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.2.2 Engine-Generator Set Grounding

Provide separate copper grounding conductors and connect them to the ground system as indicated. When work in addition to that indicated or specified is required to obtain the specified ground resistance, the provision of the contract covering "Changes" shall apply.

3.2.3 Connections

Make joints in grounding conductors by exothermic weld or compression connector. Exothermic welds and compression connectors shall be installed as specified in Section 33 71 02.00 20 UNDERGROUND ELECTRICAL DISTRIBUTION paragraph entitled "Grounding."

3.2.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 START-UP ENGINEER

Provide the services of a qualified factory trained start-up engineer, regularly employed by the engine-generator set manufacturer. The start-up services shall include conducting preliminary operations and functional acceptance tests. The start-up engineer shall be present at the engine generator set installation site, full-time, while preliminary operations and functional acceptance tests are being conducted.

3.4 PREREQUISITES FOR FUNCTIONAL ACCEPTANCE TESTING

Completion of the following requirements is mandatory prior to scheduling functional acceptance tests for the engine-generator set and auxiliary equipment.

3.4.1 Piping Tests

Complete as specified in Section 33 52 10 SERVICE PIPING, FUEL SYSTEMS.

3.4.2 Generator Sets

Complete as specified in Paragraph Acceptance Checks and Tests.

3.4.3 Preliminary Operations

The start-up engineer shall conduct manufacturer recommended start-up procedures and tests to verify that the engine-generator set and auxiliary equipment are ready for functional acceptance tests. Give the Contracting Officer 15 days' advance notice that preliminary operations will be conducted. After preliminary operation has been successfully conducted, the start-up engineer will notify the Contracting Officer in writing stating the engine-generator set and auxiliary equipment are ready for functional acceptance tests.

3.4.4 Preliminary Assembled Operation and Maintenance Manuals

Preliminary assembled operation and maintenance manuals shall have been submitted to and approved by the Contracting Officer. Manuals shall be prepared as specified in the paragraph entitled "Assembled Operation and Maintenance Manuals."

3.4.5 Functional Acceptance Test Procedure

Test procedure shall be prepared by the start-up engineer specifically for the engine-generator set and auxiliary equipment. The test agenda shall cover the requirements specified in the paragraph entitled "Functional Acceptance Tests." The test procedure shall indicate in detail how tests are to be conducted. A statement of the tests that are to be performed without indicating how the tests are to be performed is not acceptable. Indicate what work is planned on each workday and identify the calendar dates of the planned workdays. Specify what additional technical support personnel is needed such as factory representatives for major equipment. Specify on which testing workday each technical support personnel is needed. Data recording forms to be used to document test results are to be submitted with the proposed test procedure. A list of test equipment and

instruments shall also be included in the test procedure.

3.4.6 Test Equipment

Test equipment and instruments shall be on hand prior to scheduling field tests or, subject to Contracting Officer approval, evidence shall be provided to show that arrangements have been made to have the necessary equipment and instruments on site prior to field testing.

3.5 FIELD QUALITY CONTROL

Give Contracting Officer 15 days' notice of dates and times scheduled for tests which require the presence of the Contracting Officer. The Contracting Officer will coordinate with the using activity and schedule a time that will eliminate or minimize interruptions and interference with the activity operations. The Contractor shall be responsible for costs associated with conducting tests outside of normal working hours and with incorporating special arrangements and procedures, including temporary power conditions. The Contractor shall provide labor, equipment, diesel fuel, test load, and consumables required for the specified tests. The test load shall be a cataloged product. Calibration of measuring devices and indicating devices shall be certified. Perform the following field tests.

3.5.1 Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations, and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.5.1.1 Circuit Breakers - Low Voltage Insulated Case/Molded Case

a. Visual and mechanical inspection

    1. Compare nameplate data with specifications and approved shop drawings.

    2. Inspect circuit breaker for correct mounting.

    3. Operate circuit breaker to ensure smooth operation.

    4. Inspect case for cracks or other defects.

    5. Verify tightness of accessible bolted connections and cable connections by calibrated torque-wrench method. Thermographic survey is not required.

    6. Inspect mechanism contacts and arc chutes in unsealed units.

b. Electrical Tests

    1. Perform contact-resistance tests.

    2. Perform insulation-resistance tests.

    3. Adjust Breaker(s) for final settings in accordance with engine-generator set manufacturer's requirements.

3.5.1.2 Current Transformers

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify correct connection.

4. Verify that adequate clearances exist between primary and secondary circuit.

5. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method. Thermographic survey is not required.

6. Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

1. Perform insulation-resistance tests.

2. Perform polarity tests.

3. Perform ratio-verification tests.

3.5.1.3 Metering and Instrumentation

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of electrical connections.

b. Electrical Tests

1. Determine accuracy of meters at 25, 50, 75, and 100 percent of full scale.

2. Calibrate watthour meters according to manufacturer's published data.

3. Verify all instrument multipliers.

4. Electrically confirm that current transformer secondary circuits are intact.

3.5.1.4 Battery Systems

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method. Thermographic survey is not required.

4. Measure electrolyte specific gravity and temperature and visually check fill level.

5. Verify adequacy of battery support racks, mounting, anchorage, and clearances.

b. Electrical tests

1. Set charger float and equalizing voltage levels.

2. Verify all charger functions and alarms.

3. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

4. Perform a capacity load test.

3.5.1.5 Engine-Generator Set

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Inspect for correct anchorage and grounding.

b. Electrical and mechanical tests

1. Perform an insulation-resistance test on generator winding with respect to ground. Calculate polarization index.

2. Perform phase rotation test to determine compatibility with load requirements.

3.5.1.6 Grounding System

a. Visual and mechanical inspection

1. Inspect ground system for compliance with contract plans and specifications.

b. Electrical tests

1. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod perform tests before any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use a portable ground testing megger in accordance with manufacturer's instructions to

test each ground or group of grounds. The instrument shall be equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

3.5.2 Functional Acceptance Tests

The tests shall be performed by the start-up engineer. Upon successful test completion, the start-up engineer shall provide the Contracting Officer with a written test report within 15 calendar days showing the tests performed and the results of each test. The report shall include the completed approved test data forms and certification from the start-up engineer that the test results fall within the manufacturer's recommended limits and meet the specified requirements performance. The report shall be dated and signed by the start-up engineer, and submitted for approval by the Contracting Officer. The Contracting Officer and NAVFAC will witness final acceptance tests. Testing shall include but not be limited to:

a. Verify proper functioning of each engine protective shutdown device and pre-shutdown alarm device. Testing of the devices shall be accomplished by simulating device actuation and observing proper alarm and engine shutdown operation.

b. Verify proper functioning of the engine overspeed trip device. Testing of the overspeed trip device shall be accomplished by raising the speed of the engine-generator set until an overspeed trip is experienced.

c. Verify proper functioning of the crank cycle/terminate relay. Testing of the relay shall be accomplished by engaging the starter motor with the engine being prevented from running. Observe the complete crank/rest cycle as described in the paragraph entitled "Crank Cycle/Terminate Relay."

d. Verify proper functioning of the following automatic and manual operations. Testing shall include but not be limited to:

    1. Loss of Utility: Initiate a normal power failure with connected test load of rated kW at 1.0 power factor. Record time delay on start, cranking time until engine starts and runs, time to come up to operating speed, voltage and frequency overshoot, and time to achieve steady state conditions with all switches transferred to emergency position.

    2. Return of Utility: Return normal power and record time delay on retransfer for each automatic transfer switch, and time delay on engine cooldown and shutdown.

    3. Manual starting

    4. Emergency stop

e. Operate the engine-generator set at rated current (amperes) until the jacket water temperature stabilizes. Stabilization will be considered to have occurred when three consecutive temperature readings remain unchanged. Continue to operate the generator set for an additional 2 hours. Record instrument readings for terminal voltage, line current, frequency (Hz), engine speed rpm, lubricating oil pressure, jacket water temperature, and ambient temperature at 5 minute intervals for

first 15 minutes and at 15 minute intervals thereafter.

3.6 DEMONSTRATION

Upon completion of the work and at a time approved by the Contracting Officer, the Contractor shall provide instructions by a qualified instructor to the Government personnel in the proper operation and maintenance of the equipment. Four Government personnel shall receive training comparable to the equipment manufacturer's factory training. The duration of instruction shall be for not less than one 8 hour working day for instruction of operating personnel and not less than one 8 hour working day for instruction of maintenance personnel.

3.6.1 Instructor's Qualification Resume

Instructors shall be regular employees of the engine-generator set manufacturer. The instruction personnel provided to satisfy the requirements above shall be factory certified by the related equipment manufacturer to provide instruction services. Submit the name and qualification resume of instructor to the Contracting Officer for approval.

3.6.2 Training Plan

Submit training plan 30 calendar days prior to training sessions. Training plan shall include scheduling, content, outline, and training material (handouts). Content shall include but not limited to the following:

3.6.2.1 Operating Personnel Training

This instruction includes operating the engine-generator set, auxiliary equipment including automatic transfer switches in all modes, and the use of all functions and features specified.

3.6.2.2 Maintenance Personnel Training

Shall include mechanical, hydraulic, electrical, and electronic instructions for the engine-generator set and auxiliary equipment including automatic transfer switches.

a. Mechanical Training: Shall include at least the following:

1. A review of mechanical diagrams and drawings.

2. Component location and functions.

3. Troubleshooting procedures and techniques.

4. Repair procedures.

5. Assembly/disassembly procedures.

6. Adjustments (how, when, and where).

7. Preventive maintenance procedures.

8. Review of flow diagram.

9. Valve locations and function.

10. Valve and hydraulic equipment adjustment and maintenance procedures.

11. Hydraulic system maintenance and servicing.

12. Lubrication points, type, and recommended procedures and frequency.

b. Electrical and Electronic Maintenance Training: Shall include at least the following:

1. A review of electrical and electronic systems including wiring diagrams and drawings.

2. Troubleshooting procedures for the machine and control systems.

3. Electrical and electronic equipment servicing and care.

4. Use of diagnostics to locate the causes of malfunction.

5. Procedures for adjustments (locating components, adjustments to be made, values to be measured, and equipment required for making adjustments).

6. Maintenance and troubleshooting procedures for microprocessor or minicomputer where applicable.

7. Circuit board repair procedures where applicable (with schematics provided).

8. Use of diagnostic tapes.

9. Recommended maintenance servicing and repair for motors, switches, relays, solenoids, and other auxiliary equipment and devices.

-- End of Section --